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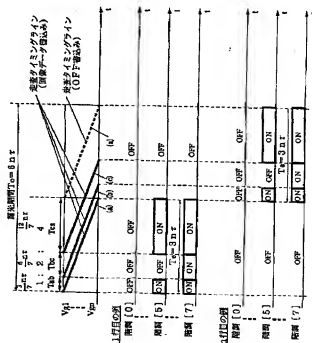
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(54) 【発明の名称】 2次元マトリクス型空間光変調素子を用いた多階調露光方法

(57) 【要約】

【課題】 駆動信号に応じて光出射、非出射の状態を択一的に取る画素部が行、列を構成して2次元マトリクス状に配置されてなる空間光変調素子を用いた多階調露光方法において、高速での多階調露光を実現する。

【解決手段】 空間光変調素子として、新たな駆動信号が入力されるまで光出射または非出射の状態を維持する画素部を有するものを用い、この空間光変調素子の全ての行を、相異なる複数の時間間隔毎に選択走査し、選択された行における各画素部に、画像データに基づいた駆動信号を入力し、上記相異なる複数の時間間隔毎になされる選択走査を時間的に多重化し、この多重化走査を受けた相異なる複数の行から、時分割によって1つの選択行を決定する。



【特許請求の範囲】

【請求項1】 駆動信号に応じて光出射、非出射の状態を択一的に取る画素部が行、列を構成して2次元マトリクス状に配置されてなる空間光変調素子を露光光の光路に配し、

この空間光変調素子により、その画素部毎に照射時間を制御した露光光を感光材料に照射して該感光材料を多階調露光させる、2次元マトリクス型空間光変調素子を用いた多階調露光方法において、

前記空間光変調素子として、新たな駆動信号が入力されるまで前記光出射または非出射の状態を維持する画素部を有するものを用い、

この空間光変調素子の全ての行を、相異なる複数の時間間隔毎に選択走査し、

選択された行における各画素部に、画像データに基づいた駆動信号を入力し、

前記相異なる複数の時間間隔毎になされる選択走査を時間的に多重化し、

この多重化走査を受けた相異なる複数の行から、時分割によって1つの選択行を決定することを特徴とする2次元マトリクス型空間光変調素子を用いた多階調露光方法。

【請求項2】 前記複数の時間間隔が、2の等比数列 $1:2:\dots:2^{(g-1)}$ (g は正の整数)であることを特徴とする請求項1記載の2次元マトリクス型空間光変調素子を用いた多階調露光方法。

【請求項3】 前記行選択の時間を τ 、前記複数の間隔数を g としたとき、基本周期 $g\tau$ で前記行選択を行なうことを特徴とする請求項1または2記載の2次元マトリクス型空間光変調素子を用いた多階調露光方法。

【請求項4】 前記画素部が、光変調部と、行選択時に各列についての駆動信号を前記光変調部に入力して光変調状態を更新、維持する回路とから構成されていることを特徴とする請求項1から3いずれか1項記載の2次元マトリクス型空間光変調素子を用いた多階調露光方法。

【請求項5】 前記光変調状態を更新、維持する回路が、単結晶半導体を含む素子で構成されたものであることを特徴とする請求項4記載の2次元マトリクス型空間光変調素子を用いた多階調露光方法。

【請求項6】 前記光変調状態を更新、維持する回路が、多結晶半導体を含む素子で構成されたものであることを特徴とする請求項4記載の2次元マトリクス型空間光変調素子を用いた多階調露光方法。

【請求項7】 前記光変調状態を更新、維持する回路が、非晶質半導体を含む素子で構成されたものであることを特徴とする請求項4記載の2次元マトリクス型空間光変調素子を用いた多階調露光方法。

【請求項8】 前記光変調素子が、強誘電性液晶からなる光変調部を有するものであることを特徴とする請求項1から7いずれか1項記載の2次元マトリクス型空間光

変調素子を用いた多階調露光方法。

【請求項9】 前記光変調素子が、駆動信号に応じて振れ角が変化するミラー素子からなる光変調部を有するものであることを特徴とする請求項1から7いずれか1項記載の2次元マトリクス型空間光変調素子を用いた多階調露光方法。

【請求項10】 前記光変調素子が、エレクトロルミネッセンス素子からなることを特徴とする請求項1から7いずれか1項記載の2次元マトリクス型空間光変調素子を用いた多階調露光方法。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明は、多階調画像を感光材料に露光する方法に関し、特に詳細には、液晶素子、ミラー素子や、エレクトロルミネッセンス素子、LED等の発光素子から構成される2次元マトリクス型空間光変調素子を使用して、感光材料を高速で多階調露光できるようにした多階調露光方法に関するものである。

【0002】

【従来の技術】近年、画像データに基づいて変調された光で感光材料、例えば銀塩感材、非銀塩系光反応性感材、光熱変換発色感材等を露光し、画像を再現するプリンター装置が各種方式で開発されている。このようなプリンター装置に要求される性能の一つに、露光速度の高速化が挙げられている。

【0003】一般的な露光方式としては、レーザ走査露光による方式が知られている。しかし、この方式は点順次露光動作であり、露光時間が長いという欠点がある。より高速露光に適した方法としては、ライン型光変調素子、または2次元マトリクス型光変調素子を利用した露光方式が知られている。前者はライン順次露光動作であり、高速露光が可能である。後者は面露光動作であり、さらに高速露光が期待できる。

2次元マトリクス型光変調素子は、駆動信号に応じて光出射、非出射の状態を択一的に取る画素部が行、列を構成して2次元マトリクス状に配置されてなるものである。なお本明細書における2次元マトリクス型光変調素子としては、画素部が液晶素子やミラー素子等、別の光源からの光を変調する素子から構成されているものは勿論のこと、該画素部がエレクトロルミネッセンス素子、LED等の発光素子から構成されているものも含むこととする。

【0004】この種の空間光変調素子の一つに、新たな駆動信号が入力されるまで上記光出射または非出射の状態を維持する画素部を備えてなるものが知られている。このタイプの空間光変調素子は、高品位なディスプレイ素子として開発、商品化されている。特にアクティブマトリクス型液晶素子のディスプレイ素子は、その代表的なものである。

【0005】ところで、この種の空間光変調素子におい

ては、面露光処理において集光率を高めるため、素子の面積が極力小さいことが望まれる。さらに高品位な画像を得るためには、素子の画素数を多くする必要がある。しかし、素子の面積を小さくし、また画素数を増やすと、当然1画素の面積が小さくなるので、素子の高精細化が要求される。

【0006】このような背景から、前述のアクティブマトリクス型液晶素子のなかでも、その基板、および画素回路（主にMOS-FET）と周辺駆動回路（主に行選択駆動回路と、列における画像信号駆動回路）が単結晶半導体で一体型に構成され、画素回路上部に反射電極を設けて液晶に電圧を供給する構成の反射型アクティブマトリクス型液晶素子が特に高集積化、高開口率の点から好ましい。

【0007】一方、アクティブマトリクス型液晶素子のなかでも、液晶材料として強誘電性液晶を用いたものは、その高速応答性（応答時間は液晶素材と液晶に印加する電圧、および温度などに依るが、数 $\mu s \sim 100 \mu s$ 程度である）から、プリンター装置用の露光素子として非常に期待されている。

【0008】しかし、強誘電性液晶は一般的に2値の安定状態しかとることができず、また反強誘電性液晶は一般的に3値の安定状態しかとることができない。そこで、それらからなる液晶素子を、プリンター装置用の露光素子として用いた場合、1回のデータ書き込みによる露光では低階調の画像しか得られない。したがって、階調数が256程度必要な画像、例えばフルカラー画像等の再現には、複数回のデータ書き込みと露光が必要となる。

【0009】ここで、強誘電性液晶を光変調部に用いた2次元マトリクス型光変調素子による多階調露光について詳しく説明する。

【0010】2次元マトリクス型光変調素子の構造
図1は、この種の空間光変調素子の画素部の断面図である。ここに示されている通り、単結晶のp-型シリコン半導体基板10上には、n-MOS-FET11と電荷蓄積容量Cstg12が形成されている。n-MOS-FET11はn+型のドレイン領域13、ソース領域14、ゲート酸化膜15、およびpoly-Si膜よりなるゲート電極16から構成される。また、電荷蓄積容量Cstg12は、p+領域17、酸化膜18、およびpoly-Si膜19で構成されている。

【0011】また、第1層間絶縁膜20を介して第1層A1配線21が形成され、これにより、ソース領域14に接続されたソース電極22が形成されている。このソース電極22により、ソース領域14と電荷蓄積容量Cstg12のpoly-Si膜19とが接続されている。なおドレイン領域13には、ドレイン電極23が接続されている。さらに第2層間絶縁膜24を介して画素電極（第2層A1）25が形成され、ソース電極22と接続されている。

【0012】画素電極25上には配向膜26が形成されてい

る。一方、対向透明基板27の片面にはITOからなる対向透明共通電極28が形成され、さらにその上に配向膜29が形成されている。上記2つの基板10、27は、各々と一体化している配向膜26、29が対向するように配置され、その間隙に強誘電性液晶30が保持されている。

【0013】図2は、図1の空間光変調素子の画素部の等価回路である。図示の通り、n-MOS-FET11のソース電極22と電荷蓄積容量Cstg12の一方、および画素電極25が接続されている。電荷蓄積容量Cstg12の他方は素子の電源グランド電位Vssに接続されている。また画素電極25と、配向膜26、29、強誘電性液晶30および対向透明共通電極28により容量C1cが形成されている。

【0014】ここで、電源グランド電位Vssを基準に、n-MOS-FET11のゲート電極電圧をVg、ドレイン電極電圧をVd、ソース電極電圧をVs、対向透明共通電極電圧をVcomとする。また、Vcomを基準に画素電極電圧を液晶層電圧V1cとする。

【0015】空間光変調素子の基本動作
図3は、空間光変調素子の基本動作を説明するための、概略の光変調光学系を示すものである。空間光変調素子1の対向透明基板側に偏光ビームスプリッター（PBS）2を配置する。光源3からの光はPBS2によりS偏光波が反射され、空間光変調素子1の対向透明基板27に入射する。入射した光は液晶30の層を介して画素電極25により反射され、再度液晶層を通過してPBS2に入射する。このとき、反射光がS偏光成分のみがPBS2を透過し、その光が出力光となる。

【0016】また図4は、同じく空間光変調素子の基本動作を説明するための、液晶層電圧V1cと液晶配向位置の関係を示している。液晶には双安定性配向を示す強誘電性液晶を使用するものとする。液晶層電圧V1cが-V1csのとき液晶配向方向が入射偏光軸と一致し、液晶層電圧V1cがV1csのとき液晶配向方向が入射偏光軸から45度の位置になるように、配向処理を行う。また、液晶配向方向が入射偏光軸から45度の位置のとき所望の出力光が得られるように、液晶素材、液晶層厚を適宜調整する。

【0017】こうすることにより、出力光は液晶層電圧V1cが-V1csのときOFFとなり、V1csのときONとなる。

【0018】次に図5は、図1～4で説明した構成における画素部の各電圧と出力光の波形とを示している。まず、n-MOS-FET11が導通状態となるようにゲート電極電圧Vgを十分高いVgsにする。同時にドレイン電極電圧VdをVd(on)にするとし、画素電圧Vsは略Vd(on)となる。その後n-MOS-FET11が非導通状態となるようにゲート電極電圧Vgを十分低いVgoffにしても、画素電圧Vsは電荷蓄積容量Cstg12と液晶層容量C1cにより略Vd(on)を保持する。したがってこの期間（図5のa）の液晶層電圧V1cは、V1c = (Vd

(on) - V_{com}) となる。

【0019】一方、n-MOS-FET11が導通状態となるようにゲート電極電圧 V_g を十分に高くし、同時にドレイン電極電圧 V_d を $V_d(off)$ にすると、画素電圧 V_s は略 $V_d(off)$ となる。その後n-MOS-FET11が非導通状態となるようにゲート電極電圧 V_g を十分低くしても、画素電圧 V_s は電荷蓄積容量 C_{stg} と液晶層容量 C_{lc} により略 $V_d(off)$ を保持する。したがってこの期間(図4の(b))における液晶層電圧 V_{lc} は略 $V_{lc} = (V_d(off) - V_{com})$ となる。

【0020】ここで対向共通電極電圧 V_{com} を
 $V_{com} = (V_d(on) + V_d(off)) / 2$
 となるように印加すると、(a)期間、(b)期間の各々の液晶層電圧 V_{lc} は、

(a)期間: $V_{lc} = (V_d(on) - V_d(off)) / 2$
 (b)期間: $V_{lc} = -(V_d(on) - V_d(off)) / 2$
 となる。このとき、(a)期間、(b)期間の液晶層電圧 V_{lc} が各々 V_{lcs} 以上、 $-V_{lcs}$ 以下になるように $V_d(on)$ 、 $V_d(off)$ を決定すると、出力光は各々ON、OFFと変調できることになる。

【0021】なお、実際にはn-MOS-FET11の寄生容量等の原因により、液晶層電圧 V_{lc} は(a)期間と(b)期間とで非対称となる場合があるが、本発明には特に影響ないので、 V_{lc} は上記式に従うものとする。

【0022】ここで、図5の T_r は誘導電性液晶の光学的な応答時間であり、これは一般的に液晶素材、液晶層電圧 V_{lc} 、温度等に依存するが、実用的には数 $\mu s \sim 100 \mu s$ 程度が得られる。画素にデータを書き込む時間は、液晶層電圧 V_{lc} を液晶の動作電圧 V_{lcs} (または $-V_{lcs}$)にするのに必要な電気的な応答時間と、上記液晶の光学的な応答時間に依存する。高速にデータを書き込むためには、これらの両者の時間を短くする必要があるが、特に液晶の光学的な応答時間は実用的に限界がある。

【0023】空間光変調素子の2次元マトリクス駆動方法

図6は、2次元マトリクス空間光変調素子の等価回路である。この例は、 m 列 $\times n$ 行の画素を有する空間光変調素子であり、 m 列 $\times n$ 行の画素回路と、画素回路に信号を与える行選択駆動回路と、画像信号駆動回路とにより構成されている。画像データは画像信号駆動回路へ転送され、また、制御信号と各駆動回路により後述するシーケンスが満たされる。ここで、同じ行の画素のゲート電極が共に接続され、行選択駆動回路の出力である行選択信号 $[V_{g1}, V_{g2}, \dots, V_{gn}]$ によって各々制御される。また、同じ列の画素のドレイン電極が共に接続され、画像信号駆動回路の出力である画像信号 $[V_{d1}, V_{d2}, \dots, V_{dm}]$ によって各々データが供給される。

【0024】なお、図6の等価回路で示される m 列 $\times n$ 行の画素回路、および行選択駆動回路と画像信号駆動回

路は、同一のシリコン基板に形成されている。

【0025】図7は、図6の回路における2次元マトリクス空間光変調素子の駆動方法を示すタイミング図である。以下、1画面分の画像信号の書き込みシーケンスを説明する。

【0026】a) 1行目の画素に書き込む画像信号を、画像信号駆動回路の出力 $[V_{d1}, V_{d2}, \dots, V_{dm}]$ から供給する。次に1行目の行選択信号である V_{g1} のみを、MOS-FETが導通となる V_{gon} にし、他の行選択信号を非導通となる V_{goff} にする。この時1行目の画素電極に各々の画像信号電圧が印加される。その後 V_{g1} をMOS-FETが非導通となる V_{goff} にしても、画素電極の電圧は殆ど変化せずに保持される。出力光はこの画素電圧に従って、図5のように応答する。このようにして1行目の画素の画像信号書き込みが行われる。この1行分の書き込み時間をとすると、

【0027】b) 2行目以降も同様のシーケンスで画像信号の書き込みを行ない、 n 行目の画像信号の書き込みが終了すると、1画面分の画像信号の書き込みが終了する。したがって、1画面分(n 行)の画像信号の書き込み時間 T_f は、 $n \times t$ となる。

【0028】露光システムの説明

図8は、上述の反射型2次元マトリクス空間光変調素子を使用した露光材料の露光システムを示している。

【0029】まず、光源3からの光は集光レンズ4で集光され、PBS2に入射する。この光のうちS偏光がPBS2で反射されて、2次元マトリクス空間光変調素子1の対向透明基板側に入射する。入射した光は液晶層を介して画素電極で反射され、再度液晶層を通過してPBS2に入射する。このとき、反射光のP偏光波のみが出力光としてPBS2を透過し、投影レンズ6によって感光材料7で結像する。感光材料7に結像する2次元の光量分布は、画像信号発生装置8によって2次元マトリクス空間光変調素子1に書き込まれた画像信号に従う。すなわち前述の図5のように、画素電圧に $V_d(on)$ を書き込むとその部分の感光材料7の光量がONとなり、画素電圧に $V_d(off)$ を書き込むとその部分の感光材料7の光量はOFFとなる。

【0030】図9は、感光材料7に対する露光のシーケンスである。まず、集光レンズ4の後に配置された光学シャッター5を閉じておく。その間に感光材料7を投影レンズ6の結像面に搬送し固定する。同時に画像信号発生装置8により、2次元マトリクス空間光変調素子1の全画素に $V_d(off)$ の信号を書き込む。その後光学シャッター5を開く。このとき出力光は全面OFFである。

【0031】この状態で画像信号発生装置8により2次元マトリクス空間光変調素子1〜1行目から順番に画像データ信号($V_d(on)$ または $V_d(off)$)を書き込む。出力光は画像信号に従って順次出力され、感光材料7を

露光する。1行目から最終のn行目までの書き込み時間は $n\tau$ である。最終のn行目に画像信号を書き込んだ後、再び1行目から出力光をOFFにするためにVd(off)の信号を書き込む。最終のn行目にVd(off)の信号を書き込むと、感光材料7への露光期間は終了する。この後に光学シャッター5が閉じられ、次の感光材料7の搬送・固定が行なわれる。

【0032】上記の露光シーケンスによると、感光材料7への露光時間 T_e は、各画素へ書き込まれた画像信号がONのとき $n\tau$ であり、OFFのときゼロである。また、この露光に必要な時間 T_o は $2n\tau$ である。

【0033】すなわち、1行の書き込み時間を τ とすると、n行、2階調の画像の露光を行なうのに必要な時間 T_o は $2n\tau$ であり、この時の感光材料7への露光時間 T_e は $n\tau$ となる。ここで、露光期間 T_o はシャッター開閉時の安定時間に加わるが、この時間は $n\tau$ に比べて非常に小さいので無視することにする。

【0034】多階調露光の説明
図10は、多階調露光を説明するための行選択信号のタイミングと走査タイミングラインの説明図である。横軸は時間軸であり、縦軸は行選択信号（上から順にVg1、Vg2、……、Vgn）を示している。この図において実線ラインは走査タイミングライン（画像データ書き込み）を示し、行選択信号によって選択される画像データ書き込み行のタイミングを記号化したものである。また、破線ラインは走査タイミングライン（OFF書き込み）を示し、行選択信号によって選択されるOFF書き込み行のタイミングを記号化したものである。

【0035】前述のような2値の光変調素子を使用して多階調露光を実現する方法として、露光時間を変えることによる多階調露光が知られている。図11は、その代表的な多階調露光方法による書き込み走査のタイミングチャートである。この図では8階調の露光タイミングを示している。1行目から最終のn行目まで行順次に画像データを書き込む走査を7回連続で繰り返す。最後の8回目の走査では、OFFを書き込む。

【0036】1回の走査時間は $n\tau$ であるので、一連のシーケンスによる露光期間 T_o は $8n\tau$ となる。図12には、図11の多階調露光方法による出力光の例を示す。なおこの図では、1行目の例を示している。

【0037】階調[0]の例では、1回目から7回目までの走査で全てOFFを書き込む。この結果、出力光は全てOFFとなり、感光材料への露光時間はゼロとなる。階調[5]の例では、1回目から5回目までの走査で全てONを書き込み、6回目と7回目の走査ではOFFを書き込む。この結果、出力光の感光材料への露光時間は $5n\tau$ となる。階調[7]の例では、1回目から7回目までの走査で全てONを書き込む。この結果、出力光の感光材料への露光時間は $7n\tau$ となる。このように階調レベルと感光材料への露光時間が比例し、多階調露

光を行なうことができる。

【0038】

【発明が解決しようとする課題】しかし、このような多階調露光方式においては、階調数が増えるのに従って露光期間 T_o も極端に長くなるという問題がある。すなわち、階調数を 2^g ($g=1, 2, 3, \dots$) とすると、露光期間 T_o は、 $T_o = 2^g n\tau$ [sec] …… (1)

となり、階調数の増大に応じて露光期間 T_o は著しく長くなる。このような多階調露光方式は、高速露光を必要とするシステムには不向きである。

【0039】本発明は上記の事情に鑑みてなされたものであり、感光材料を高速で多階調露光できる、2次元マトリクス型空間光変調素子を用いた多階調露光方法を提供することを目的とするものである。

【0040】

【課題を解決するための手段】本発明による2次元マトリクス型空間光変調素子を用いた多階調露光方法は、駆動信号に応じて光射出、非射出の状態を択一的に取る画素部が、行、列を構成して2次元マトリクス状に配置されてなる空間光変調素子を露光光の光路に配し、この空間光変調素子により、その画素部毎に照射時間を制御した露光光を感光材料に照射して該感光材料を多階調露光させる。2次元マトリクス型空間光変調素子を用いた多階調露光方法において、空間光変調素子として、新たな駆動信号が入力されるまで光射出または非射出の状態を維持する画素部を有するものを用い、この空間光変調素子の全ての行を、相異なる複数の時間間隔毎に選択走査し、選択された行における各画素部に、画像データに基づいた駆動信号を入力し、上記相異なる複数の時間間隔毎になされる選択走査を時間的に多重化し、この多重化走査を受けた相異なる複数の行から、時分割によって1つの選択行を決定するようにしたことを特徴とするものである。

【0041】なお上記複数の時間間隔は、2の等比数列 $1:2:\dots:2^{(g-1)}$ (g は正の整数) であることが望ましい。

【0042】また、上記行選択の時間を τ 、上記複数の間隔数を g としたとき、行選択の基本周期は $g\tau$ とするのが望ましい。

【0043】一方2次元マトリクス型空間光変調素子としては、画素部が、光変調部と、行選択時に各列についての駆動信号を上記光変調部に入力して光変調状態を更新、維持する回路とから構成されているものを用いるのが望ましい。

【0044】そのようにする場合、光変調状態を更新、維持する回路としては、単結晶半導体を含む素子で構成されたものや、多結晶半導体を含む素子で構成されたものや、非晶質半導体を含む素子で構成されたものを好適に用いることができる。

【0058】ここで本発明の多階調露光方法によると、階調数が多いほど、従来方法と比べて高速露光の効果が顕著になる。以下、この点について詳しく説明する。今、階調数を 2^g とする。このとき本発明によれば、画像データ書き込み走査タイミングラインは g 本となり、各走査タイミングラインの間隔比は $1:2:4:\cdots:2^{(g-1)}$ [g は正の整数] となる。また各走査タイミングラインに従って行なわれる行選択の周期は g 本に

なる。よって、階調数 2^8 のときの露光期間 T_0 は、下の式の通りとなる。

$$[0059] T_0 = 2gn\tau \quad [\text{sec}] \cdots \cdots (2)$$

以下、本発明と従来方法による露光期間 T_0 の比較を具
[条件] $\tau = 20 \mu\text{s}$

行数 n	2040	2044	2046	2047	4095
露光階調数 2^8	$2^8=256$	$2^9=512$	$2^{10}=1024$	$2^{11}=2048$	$2^{12}=4096$
従来方法による 露光期間 T_0 [sec]	10.44	20.93	41.90	83.85	335.46
本発明による 露光期間 T_0 [sec]	0.65	0.74	0.82	0.90	1.97

【0061】この表1中の数値は、各々式(1)、
(2)から計算して求めたものである。条件の数値は、特に高精細静止画像(1辺の画素数2000以上、画像階調数256程度)の2次元露光を対象とした。また、露光階調数は階調カーブの補正などを考慮すると画像の階調数よりも多くする必要があり、256~4096とした。また、1行の書き込み時間 τ は $20 \mu\text{s}$ とした。
【0062】表1の結果から明らかなように、本発明による場合の露光速度は従来と比べ、256階調では16倍、4096階調では約170倍となり、階調数の増加にもなつて顕著な効果があることが分かる。

【0063】なお、上記の実施形態では、階調数を 2^8 (g は正の整数)としたが、これ以外の階調数でも本発明は有効に作用する。今、階調数を h とした場合、画像データ書き込み走査タイミングラインを g 本(g は $2^8 \geq h$ を満たす最小の整数)とする。露光期間 T_0 は式(2)により計算される。

【0064】図17は、本発明による露光期間と階調数の関係を示したものであるが、どの階調数であっても、従来方法による露光期間よりは非常に短縮されている。なお図17で明らかなように、本発明においては階調数が 2^8 (g は正の整数)のときがより効果的である。

【0065】また本発明において、各走査タイミングラインの間隔(Tab:Tbc:……)は、厳密に2の等比数列($1:2:\cdots:2^{(g-1)}$)に設定することが望ましく、具体的には

$$\begin{aligned} & (\text{Tab:Tbc:}\cdots) \\ & = (1:2:\cdots:2^{(g-1)})gn\tau/(2^8-1) \end{aligned}$$

であることが望ましい。また、(Tab:Tbc:……)は、複数(g 本)の走査タイミングラインで時分割により行選択を行なう基本周期 $g\tau$ の整数倍である必要性があり、したがって

$$n=k(2^8-1) \quad \{k \text{は正の整数}\}$$

であることが望ましい。しかし、実際には $n=k(2^8-1)$ (k は正の整数)でない行数 n が存在する。この場合の解決手段の一つとしては、実際の素子の行数を n' としたとき、

$$n=k(2^8-1) \quad \{k \text{は正の整数}\} \geq n'$$

的に行なう。表1は、従来方法と本発明による露光期間 T_0 の比較例を示している。

【0060】
[表1]

となる最小の n の値を仮想の行数として各走査タイミングラインの間隔(Tab:Tbc:……)を
(Tab:Tbc:……)

$= (1:2:\cdots:2^{(g-1)})gn\tau/(2^8-1)$
に設定する。このようにすると、実際の素子の行数 n' 以外に($n-n'$)行余ることになるが、この余った行はダミー行として走査すればよい。

【0066】一例として、 $n'=2000$ 、 $2^8=2048$ ($g=11$)とした場合、仮想行数 $n=k(2^8-1)$ (k は正の整数)
 $=2047$ ($k=1$)とする。これにより、
(Tab:Tbc:……)

$= (1:2:\cdots:2^{(g-1)})gn\tau/(2^8-1)$
 $= (1:2:\cdots:1028)g\tau$
と厳密に設定することができる。このとき、($n-n'$) $=48$ 行が余るが、それらはダミー行として走査すればよい。

【0067】さらに本発明においては、各走査タイミングラインの間隔(Tab:Tbc:……)を厳密に2の等比数列($1:2:\cdots:2^{(g-1)}$)とせず、実用上問題が無い間隔に設定してもよい。一例として、 $n=2000$ 、走査タイミングラインを $g=11$ 本とした場合、
(Tab:Tbc:……)

$= (1:2:4:\cdots:256:512:977)$
と設定する。右辺の数列の最後の数が2の等比数列になっていないが、右辺の数列の級数は2000であるので、(Tab:Tbc:……)は行選択の基本周期 $g\tau$ の整数倍であり、設定した間隔による行選択走査が可能となる。ここで、最後の数が977であるため、 $2^8(=2048)$ の値からは47の組み合わせが重複し、最終的な階調数は $2^8-47=2001$ 階調となる。しかし、2001階調でも実用上問題がなければ、本発明の効果は十分に得られる。

【0068】次に、本発明の露光方法による光の利用効率について説明する。 $n=k(2^8-1)$ (k は正の整数)のとき、本発明によれば、露光期間 T_0 は $T_0=2gn\tau$ であり、感光材料への露光時間 T_e は $T_e=gn$

τ である。したがって、光の利用効率 η は、 $\eta = (T_e / T_o) \times 100 = 50\%$ となり、行数、階調数に依らず実用上問題にならない十分な光利用効率を得られる。

【0069】 $n = k(2^s - 1)$ (k は正の整数)でない条件とよきのときは、前述したように k を正の整数とするような仮想行数 n' で走査が行われ、 $2^{n'} - n$ 分だけ余分な走査時間を必要とする。したがって、光の利用効率は50%以下になる場合があるが、その低下は小さく実用上問題にならない。

【0070】なお、以上説明した実施形態で使用される2次元マトリクス型空間光変調素子で、画素部の光出射、非出射の状態を維持する回路(図1参照)は、 n -MOS-FETと蓄積容量Cstgとで構成されていたが、蓄積容量Cstgが無くて動作上問題とならなければ、この蓄積容量は省略可能である。

【0071】また図1の回路は単結晶半導体で構成されていたが、図18のように多結晶半導体で構成されてもよい。この図18の画素部回路は、MOS-FETをガラス基板50上にpoly-Si TFTプロセスで形成するものである。なお同図中、51はゲート絶縁膜、52は層間絶縁膜、53は画素電極(A1)、54はソース電極、55はゲート電極、56はドレイン電極である。

【0072】また図19に示した例のように、画素部回路は非晶質半導体で構成されてもよい。この図19の画素部回路は、画素部のMOS-FETをガラス基板60上にa-Si TFTプロセスで形成してなるものである。なお同図中、61はゲート絶縁膜(SiNx)、62は層間絶縁膜、63は画素電極(A1)、64はソース電極、65はゲート電極、66はドレイン電極、67はチャンネル保護膜(SiNx)である。

【0073】また、周辺の駆動回路が単結晶半導体で構成され、画素部が多結晶半導体もしくは非晶質半導体で構成された複合構成が採用されてもよい。

【0074】さらに、画素部の光出射、非出射の状態を維持する回路は、図20に示すように、SRAM回路などの2値メモリ回路で構成されてもよい。この図20の例では、データ信号Vd、/Vdより1または0のデータが供給されると同時に、行選択信号/WEにSRAMからのデータ書き込みをイネーブルにするパルスが与えられ、そのSRAMに1または0のデータが書き込まれ、出力電圧Vsは保持される。液晶は書き込まれたデータに従って光変調を行ない、その状態は、新たにSRAMのデータが更新されるまで維持される。

【0075】また光変調素子としては、電圧によって振れ角が変化するミラー素子を光変調部として備えるものでもよい。この素子において、書き込まれたデータが1のときは、ミラーの振れ角が一方の方向に安定して、垂直入射した光は一方の角度に反射される。一方、データが0のときは、ミラーの振れ角が他方の方向に安定して、

垂直入射した光は他方の角度に反射される。このようなミラー素子により構成される2次元マトリクス光変調素子を本発明の多階調露光方法に適用する場合は、素子からの一方の反射光のみ直接出力光として感光材料に結像露光できる。

【0076】また光変調素子としては、発光型素子を光変調部として備えるものでもよい。そのような発光型素子としては、電界で発光する無機の薄膜EL(エレクトロルミネッセンス)素子、電流で発光するキャリア注入型発光素子である有機EL(エレクトロルミネッセンス)素子、化合物半導体で構成されるLED等が挙げられる。このような発光型素子により構成される2次元マトリクス光変調素子を本発明の多階調露光方法に適用する場合は、素子から発光される光を直接出力光として感光材料に結像露光できる。

【0077】一例として図21には、電界で発光する無機の薄膜EL素子を光変調部とした2次元マトリクス空間光変調素子の画素部の等価回路を示す。この図21中、70が薄膜EL、71はその画素電極、72は対向電極である。

【0078】この回路においては、行選択信号Vgの選択パルスにより、データ信号Vdから1または0のデータがMOS-FETのTR1に書き込まれる。TR1の出力電圧Vsは、書き込まれたデータが1の時、MOS-FETのTR2が十分導通状態となるような電圧で保持される。書き込まれたデータが0の時は、TR2が十分非導通状態となるような電圧で保持される。TR1の出力電圧Vsは、新たなデータが書き込まれるまで保持される。薄膜EL70はTR2と直列接続され、TR2の一方は回路のグランド電位Vssに接続され、薄膜EL70の対向電極72は共通電源Vacに接続されている。

【0079】Vacは交流電圧で代表的には20kHz、100Vrms程度の電圧が供給されている。TR2が導通状態のとき、薄膜EL70間の電圧Velは略Vacとなり、薄膜EL70が発光する。TR2が非導通状態のとき、薄膜EL70間の電圧Velは薄膜EL70が発光する電圧より低くなり、薄膜EL70は発光しない。したがって、データ1が書き込まれると発光を持續し、データ0が書き込まれると発光は行なわれなくなる。

【0080】また図22は、薄膜ELを用いる2次元マトリクス空間光変調素子の画素部の断面図である。この例では、半導体基板80上に図21に示したような画素回路81が形成され、層間絶縁層82を介して画素電極(A1)等の金属反射膜83が形成されている。さらに絶縁層84、EL発光層(一例としてZnS:Mn薄膜)85、絶縁層86、対向透明電極(ITOなど)87を順に積層して、画素部が形成されている。対向透明電極87には共通電源Vacが供給される。EL発光層85から発した光は、画素電極83で反射するなどして、最終的には図22中の上方に射出する。

【0081】なお本発明の多階調露光方法は、他の階調露光方法（面積階調、光強度変調方法、ディザ法など）と組み合わせることも可能である。

【図面の簡単な説明】

【図1】本発明に用いられ得る空間光変調素子の画素部の断面図

【図2】上記空間光変調素子の画素部の等価回路図

【図3】上記空間光変調素子を用いた光変調光学系を示す概略図

【図4】液晶層電圧と液晶配向位置の関係を示す説明図

【図5】上記画素部の各電圧と出力光波形を示すグラフ

【図6】2次元マトリクス型空間光変調素子の等価回路図

【図7】2次元マトリクス型空間光変調素子の駆動方法を示す概略図

【図8】空間光変調素子を用いた露光システムの概略図

【図9】従来の多階調露光方法における感光材料への露光シーケンスを示す概略図

【図10】従来方法における行選択信号タイミングと走査タイミングラインを示す概略図

【図11】従来の多階調露光方法による書き込み走査のタイミングチャート

【図12】従来の多階調露光方法による出力光の変調状態を示す概略図

【図13】本発明の多階調露光方法における走査のタイミングチャート

【図14】図13中の一時刻における行選択信号タイミングと走査タイミングラインを示す概略図

【図15】図13中の別の時刻における行選択信号タイミングと走査タイミングラインを示す概略図

【図16】本発明の多階調露光方法による出力光の変調状態を示す概略図

【図17】本発明による露光期間と階調数との関係を示すグラフ

【図18】多結晶半導体で構成された画素部の断面図

【図19】非晶質半導体で構成された画素部の断面図

【図20】SRAM回路で構成された画素部の断面図

【図21】薄膜ELからなる画素部の等価回路図

【図22】薄膜ELからなる画素部の断面図

【符号の説明】

1 2次元マトリクス型空間光変調素子

2 P B S

3 光源

4 集光レンズ

5 シャッター

6 投影レンズ

7 感光材料

8 画像信号発生装置

10 p-型シリコン半導体基板

11 n-MOS-FET

12 電荷蓄積容量

13 ドレイン領域

14 ソース領域

15 ゲート酸化膜

16 ゲート電極

17 p+領域

18 酸化膜

19 poly-Si膜

20 第1層間絶縁膜

21 第1層A1配線

22 ソース電極

23 ドレイン電極

24 第2層間絶縁膜

25 画素電極（第2層A1）

26 配向膜

27 対向透明基板

28 対向透明共通電極

29 配向膜

50 ガラス基板

51 ゲート絶縁膜

52 層間絶縁膜

53 画素電極（A1）

54 ソース電極

55 ゲート電極

56 ドレイン電極

60 ガラス基板

61 ゲート絶縁膜（SiNx）

62 層間絶縁膜

63 画素電極（A1）

64 ソース電極

65 ゲート電極

66 ドレイン電極

67 チャンネル保護膜（SiNx）

70 薄膜EL

71 画素電極

72 対向電極

80 半導体基板

81 画素回路

82 層間絶縁層

83 画素電極

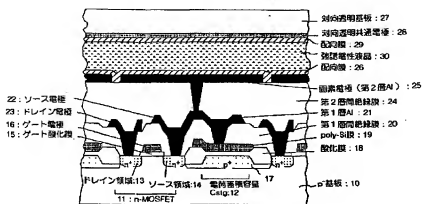
84 絶縁層

85 EL発光層

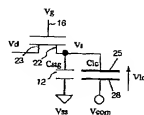
86 絶縁層

87 対向透明電極

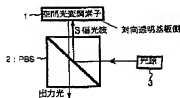
【図1】



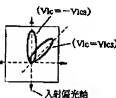
【図2】



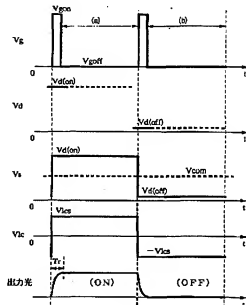
【図3】



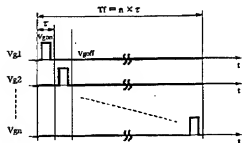
【図4】



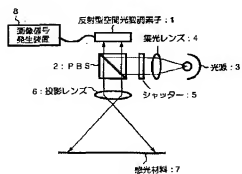
【図5】



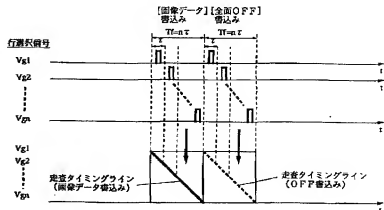
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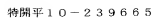


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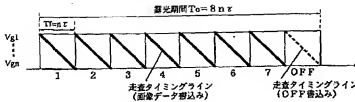


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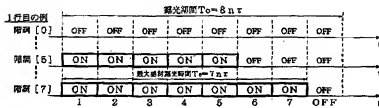




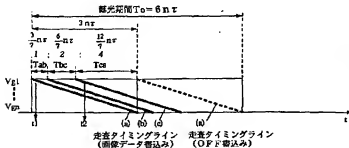
【図 11】



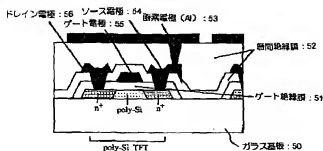
【図 12】



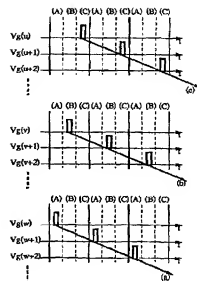
【図 13】



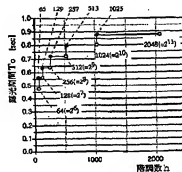
【図 18】



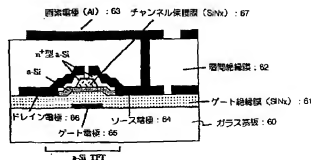
【図 15】



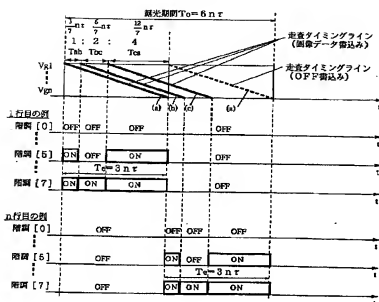
【図 17】



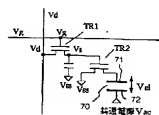
【図 19】



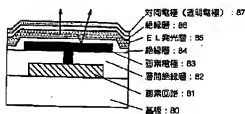
【図16】



【図21】



【図22】



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(54) [Title of the Invention] MULTI-GRADATION EXPOSING METHOD
USING TWO-DIMENSIONAL MATRIX TYPE SPATIAL OPTICAL MODULATION
ELEMENT

(57) [Abstract]

[Problem] To realize multi-gradation exposure at a high speed
in a multi-gradation exposure method that uses a spatial optical

modulation element consisting of pixel portions, which alternately take a state of light emission or non-emission according to a drive signal, constituting rows and columns to be arranged in a two-dimensional matrix shape.

[Means for Resolution] A spatial optical modulation element having pixel portions, which maintain a state of light emission or non-emission until a new drive signal is inputted, is used as the spatial optical modulation element, all rows of this spatial optical modulation element are selectively scanned for each of plural time intervals different from each other, a drive signal based on image data is inputted in each pixel portion in a selected row, selective scanning performed for each of the plural time intervals different from each other is multiplexed on a time basis, and one selected row is decided by time division out of the plural rows subjected to this multiplex scanning.

[Claims]

[Claim 1] A multi-gradation exposure method using a two-dimensional matrix type spatial optical modulation element in which a spatial optical modulation element including pixel portions, which alternately take a state of light emission or non-emission according to a drive signal, constituting rows and columns being arranged in a two-dimensional matrix shape is arranged in an optical path of exposure light, and exposure light, an irradiation time of which is controlled for each pixel portion by this spatial optical modulation element, is irradiated on a photosensitive material to apply multi-gradation exposure to the photosensitive material, characterized in that

an element having pixel portions maintaining a state of

light emission or non-emission until a new drive signal is inputted is used as the spatial optical modulation element,

all rows of the spatial optical modulation element are selectively scanned for each of plural time intervals different from each other,

a drive signal based on image data is inputted to each pixel portion in a selected row,

the selective scanning performed for each of the plural time intervals different from each other is multiplexed on a time basis, and

one selected row is decided by time division out of the plural rows different from each other subjected to this multiplex scanning.

[Claim 2] A multi-gradation exposure method using a two-dimensional matrix type spatial optical modulation element according to claim 1, characterized in that the plural time intervals are geometric series of 2, 1:2: :2^(g-1) {g is a positive integer}.

[Claim 3] A multi-gradation exposure method using a two-dimensional matrix type spatial optical modulation element according to claim 1 or 2, characterized in that, when it is assumed that a time of the row selection is τ and the number of said plural time intervals is g, the row selection is performed at a basic cycle of $g\tau$.

[Claim 4] A multi-gradation exposure method using a two-dimensional matrix type spatial optical modulation element according to any one of claims 1 to 3, characterized in that the pixel portion comprises an optical modulation portion and a circuit for inputting a drive signal for each row in the optical modulation portion at the time of row selection to update and

maintain an optical modulation state.

[Claim 5] A multi-gradation exposure method using a two-dimensional matrix type spatial optical modulation element according to claim 4, characterized in that the circuit for updating and maintaining an optical modulation state is one comprising an element including a monocrystal semiconductor.

[Claim 6] A multi-gradation exposure method using a two-dimensional matrix type spatial optical modulation element according to claim 4, characterized in that the circuit for updating and maintaining an optical modulation state is one comprising an element including a multi-crystal semiconductor.

[Claim 7] A multi-gradation exposure method using a two-dimensional matrix type spatial optical modulation element according to claim 4, characterized in that the circuit for updating and maintaining an optical modulation state is one comprising an element including an amorphous semiconductor.

[Claim 8] A multi-gradation exposure method using a two-dimensional matrix type spatial optical modulation element according to any one of claims 1 to 7, characterized in that the optical modulation element is one having an optical modulation portion including a ferroelectric liquid crystal.

[Claim 9] A multi-gradation exposure method using a two-dimensional matrix type spatial optical modulation element according to any one of claims 1 to 7, characterized in that the optical modulation element is one having an optical modulation portion including a mirror element, a deflection angle of which changes according to a drive signal.

[Claim 10] A multi-gradation exposure method using a two-dimensional matrix type spatial optical modulation element according to any one of claims 1 to 7, characterized in that

the optical modulation element comprises an electroluminescent element.

[Detailed Description of the Invention]

[0001]

[Technical Field to which the Invention Belongs] The present invention relates to a method of exposing a multi-gradation image on a photosensitive material, and in particular to a multi-gradation exposing method that makes it possible to apply multi-gradation exposure to a photosensitive material at a high speed using a two-dimensional matrix type spatial optical modulation element constituted by a liquid crystal element, a mirror element, an electroluminescence element, or a light emitting element such as an LED element.

[0002]

[Prior Art]

In recent years, a printer apparatus has been developed with various systems, which exposes a photosensitive material, for example, a silver salt photosensitive material, a non-silver salt optical reaction color development photosensitive material, a photo-thermal conversion color development sensitive material, or the like, which is modulated based on image data, to reproduce an image. One of performances required of such a printer apparatus includes increase in an exposure speed.

[0003]

As a general exposure system, there is known a system according to a laser scanning exposure. However, this system adopts a point-successive exposure operation and has a disadvantage in that an exposure time is long. As a method suitable for a higher speed exposure, there is known an exposure

system that utilizes a line type optical modulation element or a two-dimensional matrix type optical modulation element. The former adopts a line-successive exposure operation and is capable of performing high speed exposure. The latter adopts a surface exposure operation, and a much higher speed exposure can be expected with the exposure system.

The two-dimensional matrix consists of pixel portions, which alternately take a state of light emission or non-emission according to a drive signal, constituting rows and columns to be arranged in a two-dimensional matrix shape. Note that, as the two-dimensional matrix type optical modulation element in this specification, it is assumed that not only one in which a pixel portion is constituted by an element for modulating light from another light source such as a liquid crystal element or a mirror element but also one in which the pixel portion is constituted by an electroluminescence element or a light emitting element such as an LED is included.

[0004]

As one of spatial optical modulation elements of this type, there is known one provided with pixel portions for maintaining the above-mentioned light emission or non-emission until a new drive signal is inputted. The spatial optical modulation element of this type is developed and commercialized as a high-definition display element. In particular, a display element of active matrix liquid crystal elements is a representative one of the high-definition display element.

[0005]

Incidentally, in the spatial optical modulation element of this type, it is desired that an area of an element is as small as possible in order to increase a light condensing ratio

in surface exposure processing. In order to obtain a higher definition image, it is necessary to increase the number of pixels of an element. However, when an area of an element is reduced and the number of pixels is increased, since an area of one pixel is naturally reduced, high precision of the element is required.

[0006]

From such a background, among the aforementioned active matrix liquid crystal elements, what is particularly preferable from the viewpoint of high integration and high aperture ratio is a reflection type active matrix liquid crystal element with a structure in which a substrate thereof, and a pixel circuit (mainly an MOS-FET) and a peripheral drive circuit (mainly a row selection drive circuit and an image signal drive circuit in a column) are integrally constituted with a monocrystal semiconductor and a voltage is supplied to a liquid crystal by providing a reflection electrode in the upper part of the pixel circuit.

[0007]

On the other hand, among the active matrix liquid crystal element, one using a ferroelectric liquid crystal as a liquid crystal material is highly expected as an exposure element for a printer apparatus due to its high speed responsiveness (a response time is in the order of several μ s to 100 μ s depending on a liquid crystal material, a voltage applied to a liquid crystal, temperature, and the like).

[0008]

However, the ferroelectric liquid crystal can generally take a binary stable state only and an anti-ferroelectric liquid crystal can generally take a ternary stable state only. Thus,

when a liquid crystal consisting of these liquid crystals is used as an exposure element for a printer apparatus, only a low-gradation image is obtained with exposure by data writing of one time. Therefore, data writing and exposure of plural times are necessary for reproduction of an image requiring the number of gradations of approximately 256, for example, a full color image or the like.

[0009]

Here, multi-gradation exposure by a two-dimensional matrix type optical modulation element using a ferroelectric liquid crystal in an optical modulation portion will be described in detail.

[0010]

Structure of a two-dimensional matrix type optical modulation element

Fig. 1 is a sectional view of a pixel portion of a spatial optical modulation element of this type. As shown in the figure, an n-MOS-FET 11 and a charge accumulation capacitor Cstg 12 are formed on a p-type silicon semiconductor substrate 10 of a monocrystal. The n-MOS-FET 11 is constituted by an n⁺ type drain area 13, a source area 14, a gate oxide film 15, and a gate electrode 16 consisting of a poly-Si film. In addition, the charge accumulation capacitor Cstg' 12 is constituted by a p⁺ area 17, an oxide film 18, and a poly-Si film 19.

[0011]

In addition, first layer Al wiring 21 is formed via a first interlayer insulating film 20, whereby a source electrode 22 connected to the source area 4 is formed. The source area 14 and the poly-Si film 19 of the charge accumulation capacitor Cstg 12 are connected by this source electrode 22. Note that

a drain electrode 23 is connected to the drain area 3. Moreover, a pixel electrode (second layer Al) 25 is formed via a second interlayer insulating film 24 and is connected to the source electrode 22.

[0012]

An orientation film 26 is formed on the pixel electrode 25. On the other hand, an opposed transparent common electrode 28 consisting of ITO is formed on one side of an opposed transparent substrate 27, and an orientation film 29 is further formed on the opposed transparent common electrode 28. The above-mentioned two substrates 10 and 27 are arranged such that the orientation films 26 and 29, which are made integral with the substrates 10 and 27, respectively, are opposed to each other, and a ferroelectric liquid crystal 30 is held in a gap between them.

[0013]

Fig. 2 is an equivalent circuit of the pixel portion of the spatial optical modulation element of Fig. 1. As shown in the figure, the source electrode 22 of the n-MOS-FET 11, one side of the charge accumulation capacitor Cstg 12, and the pixel electrode 25 are connected. The other side of the charge accumulation capacitor Cstg 12 is connected to a power supply ground potential V_{ss} of the electrode. In addition, a capacitor Clc is formed by the pixel electrode 25, the orientation films 26 and 29, the ferroelectric liquid crystal 30, and the opposed transparent common electrode 28.

[0014]

Here, a gate electrode voltage of the n-MOS-FET 11 is assumed to be V_g , a drain electrode voltage is assumed to be V_d , a source electrode voltage is assumed to be V_s , and an opposed

transparent common electrode voltage is assumed to be V_{com} with a power supply ground potential V_{ss} as a reference. In addition, a pixel electrode voltage is assumed to be a liquid crystal layer voltage V_{lc} with V_{com} as a reference.

[0015]

Basic operation of a spatial optical modulation element

Fig. 3 shows a schematic optical modulation optical system for explaining a basic operation of a spatial optical modulation element. A polarizing beam splitter (PBS) 2 is arranged on an opposed transparent substrate side of a spatial optical modulation element 1. An S polarized light wave of light from a light source 3 is reflected by the PBS 2 and incident in an opposed transparent substrate 7 of the spatial optical modulation element 1. The incident light is reflected by the pixel electrode 25 via a layer of a liquid crystal 30 and incident in the PBS 2 passing through the liquid crystal layer again. At this point, only a P polarized light component of the reflected light is transmitted through the PBS 2 and light thereof becomes output light.

[0016]

In addition, Fig. 4 shows a relationship between a liquid crystal layer voltage V_{lc} and a liquid crystal orientation position for also explaining the basic operation of the spatial optical modulation element. It is assumed that a ferroelectric liquid crystal showing bistable orientation is used as a liquid crystal. Orientation processing is performed such that a liquid crystal orientation direction coincides with an incident polarized light axis when the liquid crystal layer voltage V_{lc} is $-V_{lc}$ s and the liquid crystal orientation direction is in a position 45 degrees from the incident polarized light axis

when the liquid crystal layer voltage V_{lc} is V_{lcs} . In addition, a liquid crystal material and a liquid crystal layer thickness are appropriately adjusted such that desired output light is obtained when the liquid crystal orientation direction is in the position 45 degrees from the incident polarized light axis.

[0017]

Consequently, the output light is turned OFF when the liquid crystal layer voltage V_{lc} is $-V_{lcs}$ and turned ON when it is V_{lcs} .

[0018]

Next, Fig. 5 shows each voltage of the pixel portion and a waveform of output light in the structure described in Figs. 1 to 4. First, the gate electrode voltage V_g is increased to a sufficiently high V_{gs} such that the n-MOS-FET 11 becomes conductive. When the drain electrode voltage V_d is simultaneously set to $V_{d(on)}$, the pixel voltage V_s is increased to about $V_{d(on)}$. Thereafter, even if the gate electrode voltage V_g is decreased to a sufficiently low V_{goff} such that the n-MOS-FET 11 becomes nonconductive, the pixel voltage V_s holds about $V_{d(on)}$ by the charge accumulation capacitor C_{stg} 12 and the liquid crystal layer capacitor C_{lc} . Therefore, the liquid crystal layer voltage V_{lc} in this period ((a) in Fig. 5) equals to $(v_{d(on)} - V_{com})$.

[0019]

On the other hand, when the gate electrode voltage V_g is increased to be sufficiently high such that the n-MOS-FET 11 becomes conductive and the drain electrode voltage V_d is simultaneously set to $V_{d(off)}$, the pixel voltage V_s drops to about $V_{d(off)}$. Thereafter, even if the gate electrode voltage V_g is decreased to be sufficiently low such that the n-MOS-FET

11 becomes nonconductive, the pixel voltage V_s holds about $V_d(\text{off})$ by the charge accumulation capacitor C_{stg} and the liquid crystal layer capacitor C_{lc} . Therefore, the liquid crystal voltage V_{lc} in this period ((h) in Fig. 4) equals to about $(V_d(\text{off}) - V_{com})$.

[0020]

Here, when the opposed common electrode voltage V_{com} is applied such that V_{com} equals to $(V_d(\text{on}) + V_d(\text{off}))/2$, the liquid crystal layer voltage V_{lc} of each of (a) period and (b) period is as follows:

$$(a) \text{ period: } V_{lc} = (V_d(\text{on}) - V_d(\text{off}))/2$$

$$(b) \text{ period: } V_{lc} = (V_d(\text{on}) - V_d(\text{off}))/2$$

In this case, when $V_d(\text{on})$ and $V_d(\text{off})$ are determined such that the respective liquid crystal layer voltages V_{lc} of the (a) period and the (b) period become V_{lcs} or more and $-V_{lcs}$ or less, respectively, output light can be modulated to be ON and OFF, respectively.

[0021]

Note that, although the liquid crystal layer voltage V_{lc} may be actually asymmetrical in the (a) period and the (b) period due to causes such as parasitic capacitance of the n-MOS-FET 11, since this does not specifically affect the present invention, it is assumed that V_{lc} conforms to the above-mentioned expression.

[0022]

Here, T_r in Fig. 5 indicates an optical response time of a ferroelectric liquid crystal. Although this generally depends on a liquid crystal material, the liquid crystal layer voltage V_{lc} , temperature, and the like, approximately several μs to 100 μs is practically obtained. Time for writing data

in a pixel depends on an electric response time required for changing the liquid crystal layer voltage V_{lc} to an operation voltage V_{lcs} (or $-V_{lcs}$) and the above-mentioned optical response time of a liquid crystal. Although it is necessary to reduce both of these times in order to write data at a high speed, in particular, the optical response time practically has a limit.

[0023]

Two-dimensional matrix drive method of a spatial optical modulation element

Fig. 6 is an equivalent circuit of a two-dimensional matrix type spatial optical modulation element. This example is a spatial optical modulation element having pixels of m columns \times n rows, which is constituted by a pixel circuit of m columns \times n rows, a row selection drive circuit for giving a signal to the pixel circuit, and an image signal drive circuit. Image data is transferred to the image signal drive circuit, and a sequence discussed later is completed by a control signal and each drive circuit. Here, gate electrodes of pixels of the same row are connected together and are controlled, respectively, by row selection signals $[V_{g1}, V_{g2}, \dots, V_{gn}]$ that are outputs of the row selection drive circuit. In addition, drain electrodes of pixels of the same column are connected together, data is supplied to the drain electrodes, respectively, by image signals $[V_{d1}, V_{d2}, \dots, V_{dm}]$ that are outputs of the image signal drive circuit.

[0024]

Note that the pixel circuit of m columns \times n rows, the row selection drive circuit and the image signal drive circuit shown in the equivalent circuit of Fig. 6 are formed on an identical silicon substrate.

[0025]

Fig. 7 is a timing chart showing a driving method of the two-dimensional matrix type spatial optical modulation element in the circuit of Fig. 6. A writing sequence of an image signal for one screen will be hereinafter described.

[0026]

a) An image signal to be written in pixels of a first row is supplied from the output [Vd1, Vd2,, Vdm] of the image signal drive circuit. Next, only Vg1 that is a row selection signal of the first row is turned into Vgon with which MOS-FET becomes conductive and the other row selection signals are turned into Vgoff with which MOS-FET becomes nonconductive. At this point, an image signal voltage is applied to each of the pixel electrodes of the first row. Thereafter, even if Vg1 is turned into Vgoff with which MOS-FET becomes nonconductive, a voltage of a pixel electrode changes little and is maintained. Output light responds as shown in Fig. 5 in accordance with this pixel voltage. In this way, image signal writing of the pixels of the first row is performed. A writing time for this first row is assumed to be τ .

[0027]

b) Writing of image signals is performed in the same sequence for the second and subsequent rows, and when writing of an image signal for the n-th row is finished, writing of image signals for one screen is finished. Therefore, a writing time Tf of image signals for one screen (n rows) is $n \times \tau$.

[0028]

Description of an exposure system

Fig. 8 shows an exposure system of a photosensitive material that uses the above-described reflection type

two-dimensional matrix type optical modulation element.

[0029]

First, light from the light source 3 is condensed by a condensing lens 4 and incident in the PBS 2. An S polarized light of this light is reflected by the PBS 2 and incident on the opposed transparent substrate side of the two-dimensional matrix type spatial optical modulation element 1. The incident light is reflected by the pixel electrode via the liquid crystal layer and incident in the PBS 2 passing through the liquid crystal layer again. In this case, only a P polarized light of the reflected light is transmitted through the PBS 2 as an output light and focused on a photosensitive material 7 by a projection lens 6. A two-dimensional distribution of amount of light focused on the photosensitive material 7 conforms to the image signal written in the two-dimensional matrix type spatial optical modulation element 1 by an image signal generation device 8. That is, as shown in the aforementioned Fig. 5, when $V_d(\text{on})$ is written in a pixel voltage, an amount of light of the photosensitive material 7 of that part becomes ON, and when $V_d(\text{off})$ is written in a pixel voltage, an amount of light of the photosensitive material 7 in that part becomes OFF.

[0030]

Fig. 9 is a sequence of exposure with respect to the photosensitive material 7. First, an optical shutter 5 arranged behind the condensing lens 4 is closed. While the optical shutter 5 is closed, the photosensitive material 7 is conveyed to a focusing surface of the projection lens 6 and fixed. At the same time, a signal of $V_d(\text{off})$ is written in all pixels of the two-dimensional matrix type spatial optical modulation element 1 by the image signal generation device 8. Thereafter,

the optical shutter 5 is opened. An output light at this point is OFF on the entire surface.

[0031]

In this state, the image data signal ($V_d(\text{on})$ or $V_d(\text{off})$) is written in the two-dimensional matrix type spatial optical modulation element 1 in order from the first row by the image signal generation device 8. Output light is sequentially outputted in accordance with the image signal and exposes the photosensitive material 7. A writing time from the first row to the last n -th row is $n\tau$. After an image signal is written in the last n -th row, a signal of $V_d(\text{off})$ is written from the first row again in order to make an output light OFF. When a signal of $V_d(\text{off})$ is written in the last n -th row, a period for exposing the photosensitive material 7 ends. Thereafter, the optical shutter 5 is closed, and conveyance and fixing of the next photosensitive material 7 are performed.

[0032]

According to the above-mentioned exposure sequence, an exposure time T_e for the photosensitive material 7 is $n\tau$ when the image signal written in each pixel is ON, and is zero when the image signal is OFF. In addition, a time T_0 required for this exposure is $2n\tau$.

[0033]

That is, when a writing time for one row is assumed to be τ , the time T_0 required for performing exposure of an image of n rows and two gradations is $2n\tau$, and the exposure time T_e for the photosensitive material 7 at this point is $n\tau$. Here, although a stabilizing time at the time of opening and closing the shutter is added to the exposure period T_0 , the stabilizing time can be neglected because it is extremely small compared

with nr .

[0034]

Description of multi-gradation exposure

Fig. 10 is an explanatory view of timing of a row selection signal and a scan timing line for explaining multi-gradation exposure. The horizontal axis is a time axis, and the vertical axis indicates row selection signals ($Vg1, Vg2, \dots, Vgn$ in order from the above). In this figure, a solid line indicates a scan timing line (image data writing), which is encoded timing of an image data writing row to be selected by the row selection signals. In addition, a broken line indicates a scan timing line (OFF writing), which is encoded timing of an OFF writing row to be selected by the row selection signals.

[0035]

As a method of using the aforementioned binary optical modulation element to realize multi-gradation exposure, there is known multi-gradation exposure by changing an exposure time. Fig. 11 is a timing chart of writing scan according to the representative multi-gradation exposure method. In this figure, exposure timing of eight gradations is shown. Scanning for writing image data from the first line to the last n -th line in a row-sequential manner is repeated seven times in a row. In scanning of the last eighth time, OFF is written.

[0036]

Since a time for one scanning is nr , the exposure period T_0 by a series of sequence is $8nr$. In Fig. 12, an example of output light according to the multi-gradation exposure method of Fig. 11 is shown. Note that, in this figure, an example of the first row is shown.

[0037]

In an example of gradation [0], OFF is written in all scanning from the first time to the seventh time. As a result, all the output light becomes OFF, and an exposure time for a photosensitive material becomes zero. In an example of gradation [5], ON is written in all scanning from the first time to the fifth time, and OFF is written in scanning from the sixth time and the seventh time. As a result, an exposure time of output light for a photosensitive material becomes 5nt. In an example of gradation [7], ON is written in all scanning from the first time to the seventh time. As a result, an exposure time of output light for a photosensitive material becomes 7nt. In this way, a gradation level and an exposure time for a photosensitive material are proportionate to each other, and multi-gradation exposure can be performed.

[0038]

[Problems that the Invention is to Solve]

However, in such a multi-gradation exposure system, there is a problem in that the exposure period T_0 becomes extremely long in accordance with the increase in the number of gradations. That is, when the number of gradations is assumed to 2^g ($g=1, 2, 3, \dots$), the exposure period T_0 is represented by the following expression:

$$T_0 = 2^g \text{ nt [sec]} \dots\dots (1)$$

And the exposure period T_0 becomes extremely long in accordance with the increase in the number of gradations. Such a multi-gradation exposure system is not appropriate for the system requiring a high-speed exposure.

[0039]

The present invention has been devised in view of the above-mentioned circumstances, and it is an object of the present

[0040]

[Means for Solving the Problems]

The multi-gradation exposure method using the two-dimensional matrix type spatial optical modulation element according to the present invention is a multi-gradation exposure method using a two-dimensional matrix type spatial optical modulation element in which a spatial optical modulation element consisting of pixel portions, which alternately take a state of light emission or non-emission according to a drive signal, constituting rows and columns to be arranged in a two-dimensional matrix shape are arranged in an optical path of exposure light, and exposure light, an irradiation time of which is controlled for each pixel portion by this spatial optical modulation element, is irradiated on a photosensitive material to apply multi-gradation exposure to the photosensitive material, the multi-gradation exposure method being characterized in that an element having pixel portions for maintaining a state of light emission or non-emission until a new drive signal is inputted is used as the spatial optical modulation element, all rows of this spatial optical modulation element are selectively scanned for each of plural time intervals different from each other, a drive signal based on image data is inputted in each pixel portion in a selected row, the selective scanning performed for each of the plural time intervals different from each other is multiplexed on a time basis, and one selected row is decided by time division out of the plural rows different

from each other subjected to this multiplex scanning.

[0041]

Note that it is desirable that the above-mentioned plural time intervals are geometric series of 2, 1:2: :2^(g-1) {g is a positive integer}.

[0042]

In addition, when it is assumed that a time of the above-mentioned row selection is τ and the number of the above-mentioned plural time intervals is g, a basic cycle of the row selection is desirably $g\tau$.

[0043]

On the other hand, as the two-dimensional matrix type spatial optical modulation element, it is desirable that the pixel portion is constituted by an optical modulation portion and a circuit for inputting a drive signal for each row in the above-mentioned optical modulation portion at the time of row selection to update and maintain an optical modulation state.

[0044]

In such a case, as the circuit for updating and maintaining an optical modulation state, one constituted by an element including a monocrystal semiconductor, one constituted by an element including a multi-crystal semiconductor, or one constituted by an element including amorphous semiconductor can be used preferably.

[0045]

In addition, as the optical modulation element, one having an optical modulation portion consisting of a ferroelectric liquid crystal, one having an optical modulation portion consisting of a mirror element, a deflection angle of which changes according to a drive signal, and one consisting of an

electroluminescent element can be used preferably.

[0046]

[Effect of the Invention]

In the method of the present invention, since all the rows of the spatial optical modulation element are adapted to be selectively scanned for each of the plural time intervals different from each other, the number of gradations can be increased markedly by combining the plural intervals of selective scanning even if the number of times of scanning is few. Moreover, since the plural selective scanning is multiplexed on a time basis and writing of image data is performed according to row selection by time division of the multiplexed selective scanning, the entire exposure time can be reduced significantly.

[0047]

[Embodiments of the Invention]

Embodiments of the present invention will be hereinafter described in detail with reference to the drawings. Fig. 13 is a timing chart of writing scan in a multi-gradation exposure method according to one embodiment of the present invention. Note that, in this figure, exposure timing of eight gradations is shown.

[0048]

Here, as a spatial optical modulation element, a drive circuit therefor, and an exposure system, for example, one as shown in Fig. 1, one as shown in Fig. 6, and one as shown in Fig. 8 can be utilized, respectively.

[0049]

In Fig. 13, solid slant lines (a), (b) and (c) are scan timing line for writing image data, and a broken slant line

(a) is scan timing line for writing OFF. Although each scan timing line is scanned for each line in order from the first line, scanning is started in the order of writing image data (a) → writing image data (b) → writing image data (c) → writing OFF (a).

[0050]

Here, when it is assumed that a time interval between the solid scan timing line (a) and the solid scan timing line (b) is T_{ab} , a time interval between the solid scan timing line (b) and the solid scan timing line (c) is T_{bc} , a time interval between the solid scan timing line (c) and the broken scan timing line (a) is T_{ca} , a ratio of these timing lines is set as $T_{ab}:T_{bc}:T_{ca} = 1:2:4$. More specifically, the ratio is set as $T_{ab}:T_{bc}:T_{ca} = (3/7)n\tau:(6/7)\tau:(12/7)n\tau$. In this way, exposure of eight gradations (2^3 gradations) can be performed by image data writing of three times in any row.

[0051]

Note that, essentially, writing scan (row selection) for plural rows cannot be performed simultaneously. Therefore, actually, timing for signals of row selection performed in accordance with the scan timing lines (a), (b) and (c) is allocated to periods (A), (B) and (C), respectively, whereby row selection is performed in time division with the periods (A), (B) and (C) in places where the scan timing lines overlap each other.

[0052]

In addition, Figs. 14 and 15 show a relationship between row selection signal timing and a scan timing line at a time t_1 and a time t_2 in Fig. 13. At the time t_1 immediately after starting exposure of Fig. 14, writing scan is performed in order

from the first row in accordance with the scan timing line (a). However, timing of a row selection signal is only taken in the period (A), thus, a cycle of row selection performed in accordance with the scan timing line (a) becomes 3τ . No row is scanned in the periods (B) and (C).

[0053]

In addition, although the scan timing lines (a), (b) and (c) overlap with each other at the time t_2 in Fig. 15, in the actual timing of a row selection signal, row selection is performed in the period (A) on the scan timing line (a), row selection is performed in the period (B) on the scan timing line (b), and row selection is performed in the period (C) on the scan timing line (c). A cycle of row selection performed in accordance with each scan timing line becomes 3τ .

[0054]

Next, Fig. 16 is an example of output light according to the multi-gradation exposure method shown in Fig. 13. In this case, since $\text{Tab:Tbc:Tca} = (3/7)\tau:(6/7)\tau:(12/7)\tau (=1:2:4)$, exposure of $2^3 = 8$ gradations can be performed.

[0055]

First, an example of the first row will be described. At the time of gradation [0], all writing data according to the image data writing scan timing line (a), (b) and (c) are turned OFF. As a result, all output light is turned OFF, and an exposure time for a photosensitive material becomes zero. At the time of gradation [5], writing data according to the image data writing scan timing lines (a), (b) and (c) are turned ON, OFF and ON, respectively. As a result, output light is turned ON for the time of $\text{Tab} + \text{Tca}$, and an exposure time for a photosensitive material becomes $(15/7)\tau$. At the time of

gradation [7], all writing data according to the image data writing scan timing lines (a), (b) and (c) are turned ON. As a result, output light is turned ON for the time of $T_{ab} + T_{ba} + T_{ca}$, and an exposure time for a photosensitive material becomes $3n\tau$.

[0056]

In this way, multi-gradation exposure in which a gradation level and an exposure time for a photosensitive material are proportionate to each other can be performed. In addition, multi-gradation exposure in which a gradation level and an exposure time for a photosensitive material are proportionate to each other for the n -th row as for the first row can be performed.

[0057]

As described above, according to the present invention, the exposure period T_0 of eight gradations becomes $6n\tau$, and exposure can be performed at a speed higher than the exposure period $8n\tau$ of the aforementioned conventional method.

[0058]

Here, according to the multi-gradation exposure method of the present invention, an effect of high-speed exposure becomes remarkable compared with the conventional method as the number of gradations increases. This point will be hereinafter described in detail. Now, the number of gradations is assumed to be 2^g . Then, according to the present invention, the number of image data writing scan timing lines is g , and a ratio of interval of each scan timing line becomes $1:2:4: \dots : 2^{(g-1)}$ [g is a positive integer]. In addition, a cycle of row selection performed in accordance with each scan timing line becomes $g\tau$. Thus, the exposure period T_0 at the time when

the number of gradations is 2^9 is represented by the following expression:

[0059]

$$T_0 = 2gnt \text{ [sec]} \cdots \cdots (2)$$

Exposure periods T_0 according to the present invention and the conventional method will be hereinafter compared specifically. Table 1 shows an example of comparison of the exposure periods T_0 according to the conventional method and the present invention.

[0060]

[Table 1]

[Condition] $\tau = 20 \mu s$

Number of rows n	2040	2044	2046	2047	4095
Number of exposure gradations 2^9	$2^8=256$	$2^9=512$	$2^{10}=1024$	$2^{11}=2048$	$2^{12}=4096$
Exposure period T_0 according to the conventional method [sec]	10.44	20.93	41.90	83.85	335.46
Exposure period T_0 according to the present invention [sec]	0.65	0.74	0.82	0.90	1.97

[0061]

Numerical values in this Table 1 are calculated from expressions (1) and (2), respectively. A numerical value of the condition is set for, in particular, two-dimensional exposure of a high-definition stationary image (the number of pixels in one side is 2000 or more, and the number of image gradations is approximately 256). In addition, it is necessary to set the number of exposure gradations larger than the number of gradations of an image taking into account correction of a gradation curve, or the like, and the number of exposure gradations is set to 256 to 4096. In addition, a writing time τ for one row is set to $20 \mu s$.

[0062]

As it is evident from the result of Table 1, compared with the conventional method, an exposure speed in the case of the present invention is 16 times as high in 256 gradations and approximately 170 times as high in 4096 gradations. It is seen that a remarkable effect is realized in accordance with the increase in the number of gradations.

[0063]

Note that, although the number of gradations is assumed to be 2^g (g is a positive integer) in the above-mentioned embodiment, the present invention acts effectively with the other numbers of gradations. Now, in the case in which the number of gradations is assumed to be h , the number of image data writing scan timing lines is assumed to be g (g is a minimum integer satisfying the condition $2^g \geq h$). The exposure period T_0 is calculated according to expression (2).

[0064]

Fig. 17 shows a relationship between an exposure period and the number of gradations according to the present invention. The exposure period is extremely reduced compared with the exposure period according to the conventional method in any number of gradations. Note that, as it is evident in Fig. 17, the present invention is most effective when the number of gradations is 2^g (g is a positive integer).

[0065]

In addition, in the present invention, an interval of each scan timing (Tab:Tbc:.....) is desirably set strictly to geometric series of 2 ($1:2:.....:2^{(g-1)}$) and, more specifically, desirably (Tab:Tbc:.....) = $(1:2:.....:2^{(g-1)}) \text{ gnt} / (2^g - 1)$. In addition, (Tab:Tbc:.....) needs to be an integer times a basic

cycle gr for performing row selection according to time division with the plural (g) scan timing lines. Therefore, it is desirable that $n = k(2^g - 1)$ (k is a positive integer). However, actually, the number of rows n exists in which n is not equal to $k(2^g - 1)$ (k is a positive integer). As one of solving means in this case, when the actual number of rows of an element is assumed to be n' , an interval of each scan timing line (Tab:Tbc:.....) is set to (Tab:Tbc:.....) = $(1:2:.....:2^{(g-1)}) \text{ gr} / (2^g - 1)$ with a minimum value of n , which is equal to $k(2^g - 1)$ (k is a positive integer) equal to or larger than n' , as the imaginary number of rows. In this way, although $(n - n')$ rows are in excess of the actual number of rows n' of the element, this excess rows only have to be scanned as dummy rows.

[0066]

As an example, in the case in which $n' = 2000$ and $2^g = 2048$ ($g = 11$), the imaginary row n is assumed to be $n = k(2^g - 1)$ (k is a positive integer) = 2047 ($k = 1$). Consequently, (Tab:Tbc:.....) can be strictly set as (Tab:Tbc:.....) = $(1:2:.....:2^{(g-1)}) \text{ gr} / (2^g - 1) = (1:2:.....:1028) \text{ gr}$. In this case, although $(n - n') = 48$ rows are in excess, they only have to be scanned as dummy rows.

[0067]

Moreover, in the present invention, the interval of each scan timing line (Tab:Tbc:.....) may be set as an interval that does not have a problem practically rather than setting it strictly as geometric series of 2. As an example, in the case in which it is assumed that $n = 2000$ and the number of scan timing lines $g = 11$, (Tab:Tbc:.....) is set as (Tab:Tbc:.....) = $(1:2:4:.....:256:512:977)$. Although the last number of the sequence on the right side is not geometric series of 2, since

series of the sequence on the right side is 2000, (Tab:Tbc:.....) is an integer times the basic cycle gr of row selection, and row selection scanning according to the set interval becomes possible. Here, since the last number is 977, forty-seven combinations are redundant out of the value of 2^9 (= 2048), and the final number of gradations is $2^9 - 47 = 2001$. However, even in the case of 2001 gradations, if there is no problem practically, the effect of the present invention can be realized sufficiently.

[0068]

Next, an efficiency of utilizing light according to the exposure method of the present invention will be described. When $n = k(2g - 1)$ (k is a positive integer), according to the present invention, the exposure period T_0 is equal to $2gnt$, and the exposure time T_e for a photosensitive material T_e is equal to gnt . Therefore, an efficiency of utilizing light η is represented as $\eta = (T_e / T_0) \times 100 = 50\%$, and a sufficient efficiency of utilizing light that does not have a problem practically can be realized without depending upon the number of rows and the number of gradations.

[0069]

At the time of a condition in which n is not equal to $k(2^g - 1)$ (k is a positive integer), scanning is performed in the imaginary number of rows n' with k as a positive integer as described above, and an excessive scanning time for a dummy row ($n' - n$) is required. Therefore, an efficiency of utilizing light may decline to 50% or less. However, the decline is small and is not a problem practically.

[0070]

Note that in the two-dimensional matrix type spatial

optical modulation element that can be used in the embodiment described above, the circuit for maintaining states of light emission and non-emission of a pixel portion (see Fig. 1) is constituted by the n-MOS-FET and the accumulation capacitor Cstg. However, if no problem occurs in operation without the accumulation capacitor Cstg, it is possible to eliminate this accumulation capacitor.

[0071]

In addition, although the circuit of Fig. 1 is constituted by a monocrystal semiconductor, it may be constituted by a polycrystal semiconductor as shown in Fig. 18. This pixel portion circuit of Fig. 18 consists of an MOS-FET of pixels formed on a glass substrate 50 by a poly-Si TFT process. Note that, in the figure, reference numeral 51 denotes a gate insulating film; 52, interlayer insulating films; 53, a pixel electrode (Al); 54, a source electrode; 55, a gate electrode; and 56, a drain electrode.

[0072]

In addition, as in the example shown in Fig. 19, the pixel portion circuit may be constituted by an amorphous semiconductor. This pixel portion circuit of Fig. 19 consists of an MOS-FET of pixels formed on a glass substrate 60 by an a-Si TFT process. Note that, in the figure, reference numeral 61 denotes a gate insulating film (SiNx); 62, an interlayer insulating film; 63, a pixel electrode (Al); 64, a source electrode; 65, a gate electrode; 66, a drain electrode; and 67, a channel protection film (SiNx).

[0073]

In addition, a complex structure may be adopted in which a peripheral drive circuit is constituted by a monocrystal

semiconductor and a pixel portion is constituted by a polycrystal semiconductor or an amorphous semiconductor.

[0074]

As shown in Fig. 20, the circuit for maintaining states of light emission or non-emission of the pixel portion may be constituted by a binary memory circuit such as an SRAM circuit as shown in Fig. 20. In the example of Fig. 20, when data of 1 or 0 is supplied from data signals V_d and \bar{V}_d and, at the same time, a pulse enabling data writing in the SRAM is given to a row selection signal \bar{W}_E , the data of 1 or 0 is written in the SRAM, and the output voltage V_s is held. The liquid crystal performs optical modulation in accordance with the written data, and the state is maintained until data of the SRAM is renewed anew.

[0075]

In addition, as the optical modulation element, one provided with a mirror element, whose deflection angle changes according to a voltage, may be used. In this element, when the written data is 1, the deflection angle of the mirror is stabilized in one direction, and light incident vertically is reflected at one angle. On the other hand, when the data is 0, the deflection angle of the mirror is stabilized in the other direction, and the light incident vertically is reflected at the other angle. In the case in which the two-dimensional matrix type optical modulation element constituted by such a mirror element is applied to the multi-gradation exposure method of the present invention, only one reflected light from the element can be focused to expose a photosensitive material as output light directly.

[0076]

In addition, as the optical modulation element, one provided with a light-emitting element as an optical modulation portion may be used. Examples of such a light-emitting element include an inorganic thin film EL (electroluminescent) element that emits light by an electric field, an organic EL (electroluminescent) element serving as a carrier injection type light-emitting element that emits light by a current, an LED constituted by a compound semiconductor, and the like. In the case in which the two-dimensional matrix type optical modulation element constituted by such a light-emitting element is applied to the multi-gradation method of the present invention, light emitted from the element can be focused to expose a photosensitive material as output light directly.

[0077]

As an example, an equivalent circuit of a pixel portion of a two-dimensional matrix type spatial optical modulation element having the inorganic thin film EL element that emits light by an electric field as an optical modulation portion is shown in Fig. 21. In this Fig. 21, reference numeral 70 denotes a thin film EL; 71, a pixel electrode thereof; and 72, an opposed electrode.

[0078]

In this circuit, data of 1 or 0 is written in a TR1 of a MOS-FET from the data signal Vd according to a selection pulse of the row selection signal Vg. The output voltage Vs of the TR1 is held at a voltage with which a TR2 of the MOS-FET comes into a conduction state sufficiently when the written data is 1. The output voltage Vs is held at a voltage with which the TR2 comes into a non-conduction state sufficiently when the written data is 0. The output voltage Vs of the TR1 is held

until new data is written. The thin film EL 70 is connected to the TR2 in series, one side of the TR2 is connected to the ground potential Vss, and the opposed electrode 72 of the thin film EL 70 is connected to a common power supply Vac.

[0079]

Vac supplies an AC voltage, representatively a voltage in the order of 20 kHz, 100 Vrms. When the TR2 is in the conduction state, a voltage Vel between the TR2 and the thin film EL 70 becomes substantially Vac, and the thin film 70 emits light. When the TR2 is in the non-conduction state, the voltage Vel between the TR2 and the thin film EL 70 becomes lower than a voltage with which the thin film EL 70 emits light, and the thin film EL 70 does not emit light. Therefore, the light emission is maintained if the data 1 is written, and the light emission is not performed any more if the data 0 is written.

[0080]

In addition, Fig. 22 is a sectional view of a pixel portion of a two-dimensional matrix type spatial optical modulation element using a thin film EL. In this example, a pixel circuit 81 as shown in Fig. 21 is formed on a semiconductor substrate 80, and a pixel electrode (reflection film of metal such as Al) 83 is formed via an interlayer insulating layer 82. Moreover, an insulating layer 84, an EL light-emitting layer (as an example, ZnS:Mn thin film) 85, an insulating layer 86, and an opposed transparent electrode (ITO, etc.) 87 are laminated in order to form the pixel portion. The common power supply Vac is supplied to the opposed transparent electrode 87. Light emitted from the EL light-emitting layer 85 is reflected by the pixel electrode 83 to finally exit upwards in Fig. 22.

[0081]

Note that it is also possible to combine the multi-gradation exposure method of the present invention with other gradation exposure method (area gradation, optical intensity modulation method, dither method, etc.).

[Brief Description of the Drawings]

[Fig. 1] Sectional view of a pixel portion of a spatial optical modulation element that can be used in the present invention

[Fig. 2] An equivalent circuit of the pixel portion of the above-mentioned spatial optical modulation element

[Fig. 3] A schematic view showing an optical modulation optical system using the above-mentioned spatial optical modulation element

[Fig. 4] An explanatory view showing a relationship between a liquid crystal layer voltage and a liquid crystal orientation position

[Fig. 5] A graph showing each voltage and an output light waveform of the above-mentioned pixel portion

[Fig. 6] An equivalent circuit diagram of a two-dimensional matrix type spatial optical modulation element

[Fig. 7] A schematic graph showing a driving method of the two-dimensional matrix type spatial optical modulation element

[Fig. 8] A schematic view of an exposure system using the spatial optical modulation element

[Fig. 9] A schematic graph showing an exposure sequence for a photosensitive material in a conventional multi-gradation exposure method

[Fig. 10] A schematic graph showing row selection signal timing and a scan timing line in the conventional method

[Fig. 11] A timing chart of write scanning according to the conventional multi-gradation exposure method

[Fig. 12] A schematic graph showing a modulation state of output light according to the conventional multi-gradation exposure method

[Fig. 13] A timing chart of scanning in the multi-gradation exposure method of the present invention

[Fig. 14] A schematic graph showing row selection signal timing and a scan timing line at one time in Fig. 13

[Fig. 15] Schematic graphs showing row selection signal timing and a scan timing line at another time in Fig. 13

[Fig. 16] A schematic graph showing a modulation state of output light according to the multi-gradation exposure method of the present invention

[Fig. 17] A graph showing a relationship between an exposure period and the number of gradations according to the present invention

[Fig. 18] A sectional view of a pixel portion constituted by a polycrystal semiconductor

[Fig. 19] A sectional view of a pixel portion constituted by a monocrystal semiconductor

[Fig. 20] A sectional view of a pixel portion constituted by an SRAM circuit

[Fig. 21] An equivalent circuit diagram of a pixel portion consisting of a thin film EL

[Fig. 22] A sectional view of a pixel portion consisting of a thin film EL

[Description of Reference Numerals]

1 Two-dimensional matrix type spatial optical modulation element

- 2 PBS
- 3 Light source
- 4 Condensing lens
- 5 Shutter
- 6 Projection lens
- 7 Photosensitive material
- 8 Image signal generation device
- 10 p-type silicon semiconductor substrate
- 11 n- MOS-FET
- 12 Charge accumulation capacitor
- 13 Drain area
- 14 Source area
- 15 Gate oxide film
- 16 Gate electrode
- 17 p+ area
- 18 Oxide film
- 19 poly- Si film
- 20 First interlayer insulating film
- 21 First layer Al wiring
- 22 Source electrode
- 23 Drain electrode
- 24 Second interlayer insulating film
- 25 Pixel electrode (second layer Al)
- 26 Orientation film
- 27 Opposed transparent substrate
- 28 Opposed transparent common electrode
- 29 Orientation film
- 50 Glass substrate
- 51 Gate insulting film
- 52 Interlayer insulating film

53 Pixel electrode (Al)
54 Source electrode
55 Gate electrode
56 Drain electrode
60 Glass substrate
61 Gate insulating film (SiNx)
62 Interlayer insulating film
63 Pixel electrode (Al)
64 Source electrode
65 Gate electrode
66 Drain electrode
67 Channel protection film (SiNx)
70 Thin film EL
71 Pixel electrode
72 Opposed electrode
80 Semiconductor substrate
81 Pixel circuit
82 Interlayer insulating layer
83 Pixel electrode
84 Insulating layer
85 EL light-emitting layer
86 Insulating layer
87 Opposed transparent electrode

FIG. 1

- 10 SUBSTRATE
- 12 CHARGE ACCUMULATION CAPACITOR Cstg
- 13 DRAIN AREA
- 14 SOURCE AREA
- 15 GATE OXIDE FILM
- 16 GATE ELECTRODE
- 18 OXIDE FILM
- 19 poly-Si FILM
- 20 FIRST INTERLAYER INSULATING FILM
- 21 FIRST LAYER Al
- 22 SOURCE ELECTRODE
- 23 DRAIN ELECTRODE
- 24 SECOND INTERLAYER INSULATING FILM
- 25 PIXEL ELECTRODE (SECOND LAYER Al)
- 26 ORIENTATION FILM
- 27 OPPOSED TRANSPARENT SUBSTRATE
- 28 OPPOSED TRANSPARENT COMMON ELECTRODE
- 29 ORIENTATION FILM
- 30 FERROELECTRIC LIQUID CRYSTAL

FIG. 3

- 1 SPATIAL OPTICAL MODULATION ELEMENT
- 3 LIGHT SOURCE
- S POLARIZED LIGHT WAVE
- OPPOSED TRANSPARENT SUBSTRATE SIDE
- OUTPUT LIGHT

FIG. 4

- INCIDENT POLARIZED LIGHT AXIS

FIG. 6

- 1 IMAGE DATA
- 2 CONTROL SIGNAL
- 3 IMAGE SIGNAL DRIVE CIRCUIT
- 4 ROW SELECTION DRIVE CIRCUIT

FIG. 8

- 1 REFLECTION TYPE SPATIAL OPTICAL MODULATION ELEMENT
- 3 LIGHT SOURCE
- 4 CONDENSING LENS
- 5 SHUTTER
- 6 PROJECTION LENS
- 7 PHOTOSENSITIVE MATERIAL
- 8 IMAGE SIGNAL GENERATION DEVICE

FIG. 9

1. CONVEY PHOTOSENSITIVE MATERIAL
2. CONVEY FIRST PHOTOSENSITIVE MATERIAL
3. EXPOSURE PERIOD $T_0 = 2\pi t$ OR MORE
4. FIXED PERIOD OF PHOTOSENSITIVE MATERIAL
5. CONVEY NEXT PHOTOSENSITIVE MATERIAL
6. SHUTTER
7. WRITE [OFF ON ENTIRE SURFACE]
8. WRITE [IMAGE DATA]
9. WRITE [OFF ON ENTIRE SURFACE]
10. ROW SELECTION SIGNAL
11. OUTPUT LIGHT
12. PHOTOSENSITIVE MATERIAL EXPOSURE TIME
13. FIRST ROW PIXEL

14. SECOND ROW PIXEL
15. N-TH ROW PIXEL
16. OUTPUT LIGHT CONFORMS TO IMAGE DATA

FIG. 10

- 1 ROW SELECTION SIGNAL
- 2 WRITE IMAGE DATA
- 3 WRITE OFF ON ENTIRE SURFACE
- 4 SCAN TIMING LINE (WRITE IMAGE DATA)
- 5 SCAN TIMING LINE (WRITE OFF)

FIG. 11

- 1 EXPOSURE PERIOD $T_0 = 8n\tau$
- 2 SCAN TIMING LINE (WRITE IMAGE DATA)
- 3 SCAN TIMING LINE (WRITE OFF)

FIG. 12

- 1 EXAMPLE OF FIRST ROW
- 2 GRADATION
- 3 EXPOSURE PERIOD $T_0 = 8n\tau$
- 4 MAXIMUM PHOTSENSITIVE MATERIAL EXPOSURE TIME $T_0 = 7n\tau$

FIG. 13

- 1 EXPOSURE PERIOD $T_0 = 6n\tau$
- 2 SCAN TIMING LINE (WRITE IMAGE DATA)
- 3 SCAN TIMING LINE (WRITE OFF)

FIG. 16

- 1 EXPOSURE PERIOD $T_0 = 6n\tau$
- 2 EXAMPLE OF FIRST ROW

- 3 GRADATION
- 4 EXAMPLE OF N-TH ROW
- 5 GRADATION
- 6 SCAN TIMING LINE (WRITE IMAGE DATA)
- 7 SCAN TIMING LINE (WRITE OFF)

FIG. 17

EXPOSURE PERIOD T_0

NUMBER OF GRADATIONS h

FIG. 18

- 50 GLASS SUBSTRATE
- 51 GATE INSULATING FILM
- 52 INTERLAYER INSULATING FILM
- 53 PIXEL ELECTRODE (Al)
- 54 SOURCE ELECTRODE
- 55 GATE ELECTRODE
- 56 DRAIN ELECTRODE

FIG. 19

- 60 GLASS SUBSTRATE
- 61 GATE INSULATING FILM (SiN_x)
- 62 INTERLAYER INSULATING FILM
- 63 PIXEL ELECTRODE (Al)
- 64 SOURCE ELECTRODE
- 65 GATE ELECTRODE
- 66 DRAIN ELECTRODE
- 67 CHANNEL PROTECTION FILM (SiN_x)

FIG. 21

COMMON POWER SUPPLY Vac

FIG. 22

80 SUBSTRATE

81 PIXEL CIRCUIT

82 INTERLAYER INSULATING LAYER

83 PIXEL ELECTRODE

84 INSULATING LAYER

85 EL LIGHT-EMITTING LAYER

86 INSULATING LAYER

87 OPPOSED ELECTRODE (TRANSPARENT ELECTRODE)